

# Correlation between Craniofacial Structures and Severity of Obstructive Sleep Apnea

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## Abstract

**Objective:** In the present paper authors evaluated, on supine lateral head films, the correlation of Upper Airway Space (UAS), posterior maxillary structures (i.e., palatal morphology), maxillo-mandibular and hyoid position with different severity of OSA evaluated on polysomnography test.

**Materials and Methods:** One hundred patients (mean age 51.4 years old; 92 man and 8 women) with OSA were enrolled in the present study. An Epworth questionnaire and a complete overnight Polysomnography (PSG) were done. Head films were taken with the patient in supine position fixed in a cephalostat, in centric occlusion, with adequate visualization of reference structures.

**Results:** The cephalometric evaluation showed how patients presented a reduction of Upper airway space, a post inclination of the mandible, an increase of the ANB Angle and an increase of palatal length, palatal height and palatal angle. At Spearman test a great correlation between IAS and OSA data, a direct correlation between the palatal length and thickness with IAS and an inverse correlation between the mandibular post inclination and backward position and IAS were evaluated.

**Conclusion:** In the present paper authors showed how PSG (AHI, SO2 and Nadir) data was correlated above all to IAS. The modification of IAS was related to the mandibular vertical and sagittal position and to palatal length and thickness.

**Keywords:** OSA; Polysomnography; Cephalometric analysis; AHI; Upper airway space

## Abbreviation

OSAs: Obstructive Sleep Apnea syndrome; ESS: Epworth Sleepiness Scale; UAS: Upper Airway Space; BMI: Body Mass Index; CPAP: Continuous Positive Airway Pressure; nCPAP: non-Continuous Positive Airway Pressure; PSG: Polysomnography; ECG: Electrocardiogram; AHI: Apnea-Hypopnea Index; SO2: Oxygen Saturation; AHI: Apnea-Hypopnea Index; SPAS: Superior upper airway; MAS: Medium Airway Space; IAS: Inferior Airway Space; PL: Palatal Length; PH: Palatal Height; PA: Palatal Angle; SNML: Mandibular Divergence to Cranial Base; HMI: Hyoid to Mandibular Line; ANB: Maxillo-mandibular angle

## Introduction

The OSAs (Obstructive Sleep Apnea syndrome) is a condition characterized by repetitive episodes of complete, apnea, or partial, hypopnea, upper airway obstruction occurring during sleep [1]. Its pathogenesis is still unclear but OSAs is divided in two categories: central or obstructive. The central OSAs is related to a lack function of neurological system; the obstructive form is related to a reduction or collapse of upper airway [2,3].

Untreated OSAs is often associated with daytime sleepiness, impaired quality of life and social life [4], many cardiovascular disease

as hypertension [5], stroke, heart failure, arterial fibrillation [6,7] and motor vehicle accidents [8]. OSAs affected 25% of adults [9], 2-7% of men and 2-5% in woman [10].

Anamnesis and questionnaires as ESS (Epworth Sleepiness Scale) and Stop Bang model (Stop-Bang Questionnaire) provide measures of the risk of OSAs [11,12]. The gold standard in the OSAs diagnosis is the polysomnography [13]. In obstructive sleep apnea Lateral Headfilms and 3D headfilm are used to evaluate the site of airflow reduction [14,15]. These provide to give information about the facial morphology and airflow spaces [16,17].

The study of craniofacial morphology to evaluate the risk of insurgence of OSAs in patients was studied [18]. The Neck circumference, Facial profile, mandible length and mandible position were the most commonly evaluated [19-21].

In the present paper authors evaluated, on supine lateral headfilms, the correlation of UAS (Upper Airway Space), posterior maxillary structures (i.e., palatal morphology), maxillo-mandibular and hyoid position with different severity of OSAs evaluated on polysomnography test.

## Material and Methods

One hundred patients (mean age 51.4 years old; 92 men and 8 women) with OSAs were enrolled in the pre-sent study. The participants and parents provided written informed consent to be

involved in the study. All patients were visited in the Otorhinolaryngology section at University of Foggia.

**Ethical consideration**

This study was based on a retrospective analysis. All patients have signed a specific informed con-sent, which allowed us to analyze the polysomnographic and radiographic data. These data were used for clinical use, and only subsequently they were subject to the statistical analysis.

**Patients selection**

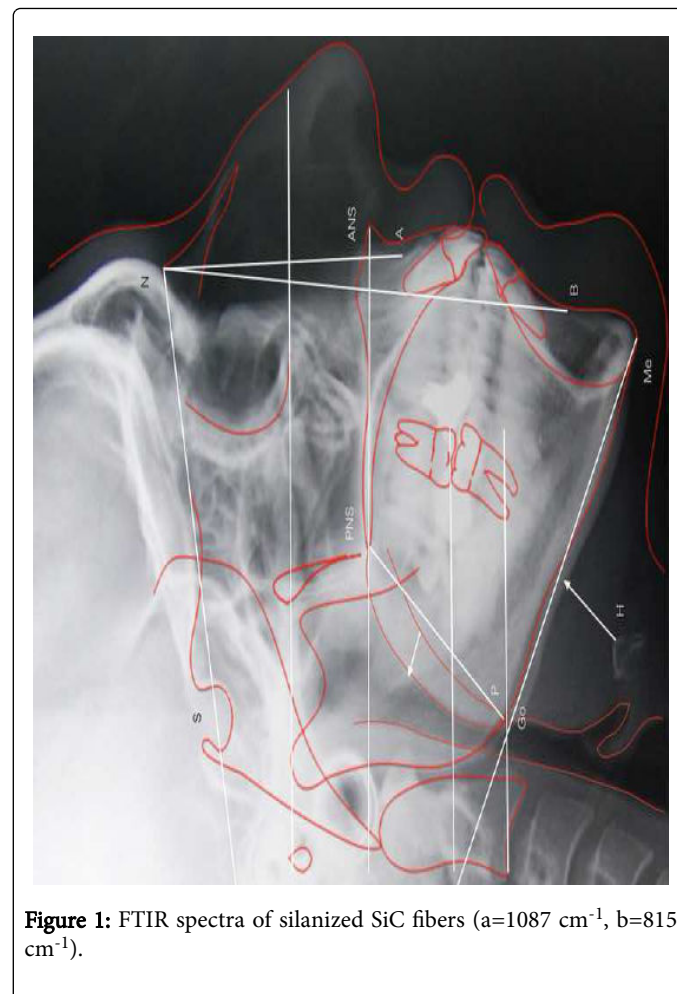
Selection of patients with Epworth questionnaire was done. Inclusion criteria were: Epworth scale upper than 10, no smokers, no BMI (body mass index) upper than 34 kg/m<sup>2</sup>, no previous maxillofacial and upper airway surgical treatment, no fixed oral appliance or mobile prosthetic rehabilitation, no CPAP (Continuous Positive Airway Pressure) previous treatment, no temporo-mandibular joint disease. Exclusion criteria were: Epworth scale lower than 10, smokers, BMI upper than 34 Kg/m<sup>2</sup>, previous maxillofacial and upper airway surgical treatment, fixed oral appliance or mobile prosthetic rehabilitation, patients in treatment with CPAP or nCPAP, temporo-mandibular joint disease.

**Instrumental evaluation**

On each patient the head film was done (Gendex GXDP-700). Head films were taken with the patient in supine position fixed in a cephalostat, in centric occlusion, with adequate visualization of reference structures. Landmarks are shown in Figure 1, and described in Table 1. To reduce the error of the method, cephalometric radiographs were selected randomly and reanalyzed 30 days later by the same examiner (M.L. and M.T.).

Each patient received a complete overnight PSG (Polysomnography). All subjects were evaluated for one night in a Sleep Laboratory using a portable device, the Embletta system (Flaga, Reykjavik, Iceland). Recording was performed after one night of adaptation to the hospital setting. Airflow was monitored by a nasal cannula and by oral thermistor. The thoracic-abdominal movements of all subjects were detected through two piezoelectric belts. Overnight

continuous recordings of oxy-gen saturation were obtained by finger pulse oximetry. Snoring was recorded by a microphone placed at the neck, and note was taken of ECG (Electrocardiogram) findings and sleep position.



Cephalometrics Landmarks	Description
<b>SPAS</b>	Superior posterior airway space (width of airway behind soft palate along a line parallel to Frankfurt plane)
<b>MAS</b>	Medium airway width measured on a line parallel to Frankfurt plane passing through posterior cusps of upper first molar
<b>IAS</b>	Inferior airway: width of airway behind tongue along a line parallel to Frankfurt plane passing through Gonion)
<b>Palatal Lenght (PL)</b>	Linear distance between Posterior Nasal Spine and the end of soft palate
<b>Palatal Angle (PA)</b>	Angle between the Anterior Nasal Spine (ANS)/posterior Nasal Spine (PNS) line and the final part of the Soft Palate (P)
<b>Palatal Thickness (PT)</b>	Linear Measurements from the lingual part to the upper airway part
<b>ANB</b>	Angle between the NA and NB lines, obtained by subtracting SNB from SNA
<b>ML-H</b>	Linear Distance between Mandibular Line and upper Hyoid bone part.
<b>SN-ML</b>	Angle between the sella-nasion (SN) line and the mandibular plane (MP).

**Table 1:** Cephalometric landmarks.

### UAS and skeletal structures evaluated

Authors evaluated and paired the data of PSG with hyoid-mandibular position and UAS as follow:

- PSG: SO2 (oxygen saturation), AHI (Apnea-Hypopnea index) and Nadir (i.e., the lowest oxygen saturation in sleep);
- Respiratory way: SPAS (Superior upper airway); MAS (Medium Airway Space) and IAS (Inferior airway space);
- Maxillary back structures: PL (Palatal Length), PH (Palatal Height), PA (Palatal Angle);
- Hyoid-mandibular structures: SNMI (Mandibular divergence to cranial base), distance of HMI (hyoid to mandibular line);
- ANB (Maxillo-mandibular angle).

### Statistical analysis

Data have been analyzed using GraphPad Prism software 6.0 (GraphPad Prism Software, SanDiego, CA, USA). Presence of normal distribution was assessed by Kolmogorov- Smirnov test and probability plot graph. To evaluate the correlation between PSG data to Maxillo-mandibular-Hyoid data a non-parametric correlation (Spearman correlation coefficient) was done. Statistical significance was set at 0.05.

### Result

The results are described in Table 2 and 3. In table 2 are described the common PSG, craniofacial and UAS data. In table 3 the correlation between the PSG data to the craniofacial structures.

	AHI	BMI	SO2	Nadir	Spas	Mas	IAS	ML-H	ANB	SN-ML	PA	PL	PT
Mean	36.28	29.24	93.28	78.8	11.82	5.92	8.909	23.21	3.832	33.15	121.1	43.27	9.78
Std. Deviation	17.96	4.542	2.543	6.769	2.173	1.417	3.398	7.514	2.012	8.005	7.014	6.191	1.912
Std. Error of Mean	1.796	0.4542	0.2543	0.6769	0.2173	0.1417	0.3398	0.7514	0.2012	0.8005	0.7014	0.6191	0.1912
Lower 95% CI of mean	32.72	28.33	92.78	77.46	11.39	5.638	8.235	21.72	3.433	31.57	119.8	42.04	9.401
Upper 95% CI of mean	39.85	30.14	93.78	80.14	12.25	6.201	9.583	24.7	4.231	34.74	122.5	44.5	10.16
Kolmogorov-Smirnoff test	No	No	No	No	Yes	No	Yes	Yes	No	No	No	No	Yes

Table 2: Mean and general evaluation of patient's test.

Parameters	AHI	SO2	Nadir	Spas	Mas	IAS	H-ML	ANB	SNML	P A	P L	P H
AHI	r	-0.34822	-0.39371	-0.12169	0.090093	0.304711	0.191222	0.033843	0.106655	0.051144	0.075106	0.192013
	p	0.000385	0.00005	0.227785	0.372707	0.002053	0.056676	0.738176	0.290899	0.613318	0.457685	0.055641
SO2	r	-0.348220418	0.319284	0.046249	-0.10673	-0.4089	-0.06726	0.015669	0.107876	-0.0206	-0.23898	-0.1146
	P	0.000384915	0.001204	0.647731	0.290546	p<0.001	0.506087	0.877033	0.285376	0.838788	0.016641	0.256218
Nadir	r	-0.393709965	0.319284	-0.04265	-0.01264	-0.33434	-0.04197	0.020116	0.016355	-0.21698	0.08192	-0.25171
	p	5.06644E-05	0.001204	0.673547	0.900708	0.000675	0.678426	0.842535	0.871695	0.030125	0.41779	0.011528
Spas	r	-0.121689437	0.046249	-0.04265	0.33467	0.115879	0.061274	0.116885	-0.05162	0.007443	0.206392	0.073192
	P	0.227785449	0.647731	0.673547	0.000666	0.250931	0.544777	0.246811	0.610018	0.941409	0.039379	0.469258
Mas	r	0.090092686	-0.10673	-0.01264	0.33467	0.268981	-0.13797	0.08665	-0.14479	0.171897	0.31771	-0.19122
	P	0.372706827	0.290546	0.900707	0.000666	0.006809	0.17104	0.391321	0.150628	0.087245	0.001277	0.056677
IAS	r	0.304711137	-0.4089	-0.33433	0.115879	0.268981	-0.05806	-0.24281	-0.32366	0.016232	0.408471	0.33864
	P	0.002053009	p<0.001	0.000674	0.250931	0.006809	0.566127	0.014927	0.00102	0.872655	p<0.001	0.000568
H-ML	r	0.191221668	-0.06726	-0.04197	0.061274	-0.13797	-0.05806	0.403115	0.277317	0.10358	0.171188	0.238204
	P	0.056675977	0.506087	0.678425	0.544777	0.17104	0.566127	p<0.001	0.005217	0.305109	0.088576	0.017007
ANB	r	0.033842917	0.015669	0.020116	0.116885	0.08665	-0.24281	0.403115	0.267579	-0.18659	0.045426	0.061128
	p	0.738175785	0.877033	0.842534	0.246811	0.391321	0.014927	p<0.001	0.007115	0.063058	0.653589	0.545735
SNML	r	0.106654528	0.107876	0.016355	-0.05162	-0.14479	-0.32366	0.277317	0.267579	0.064116	-0.2765	-0.04408

	P	0.290898735	0.285376	0.871694	0.610018	0.150628	0.00102	0.005217	0.007115		0.526242	0.005357	0.663235
PA	r	0.05114414	-0.0206	-0.21698	0.007443	0.171897	0.016232	0.10358	-0.18659	0.064116		0.015318	-0.11603
	p	0.613318484	0.838788	0.030125	0.941409	0.087245	0.872655	0.305109	0.063058	0.526242		0.879764	0.250304
P L	r	0.075105647	-0.23898	0.08191	0.206392	0.31771	0.408471	0.171188	0.045426	-0.2765	0.015318		0.394957
	p	0.457685335	0.016641	0.41779	0.039379	0.001277	p<0.001	0.088576	0.653589	0.005357	0.879764		p<0.001
PH	r	0.192013064	-0.1146	-0.25171	0.073192	-0.19122	0.33864	0.238204	0.061128	-0.04408	-0.11603	0.394957	
	p	0.055640775	0.256218	0.011528	0.469258	0.056677	0.000568	0.017007	0.545735	0.663235	0.250304	p<0.001	

Table 3: Spearman test results.

**Kolmogorov-Smirnov test**

Spas, IAS, ML-H and PT passed the test while AHI, BMI, SO2, Nadir, MAS, ANB, SN-ML, PA and PL did not pass the test.

0.2191, p<0.05). IAS presented a great relation with PSG data. IAS had an inverse relation with SO2 (r: -0.4126, p<0.001) and Nadir (r: -0.2169, p<0.05); a direct relation between IAS and AHI was shown (r: 0.2249, p<0.001).

**OSA severity- UAS (Table 4)**

Spas presented no relation with OSA severity (p=ns). MAS had no relation with OSA severity (p=ns) but presented a relation with IAS (r:

Parameters		AHI	SO2	Nadir	Spas	Mas	IAS
AHI	r		-0.34822	-0.39371	-0.12169	0.090093	0.304711
	p		0.000385	0.00005	0.227785	0.372707	0.002053
SO2	r	-0.34822		0.319284	0.046249	-0.10673	-0.4089
	p	0.000385		0.001204	0.647731	0.290546	p<0.001
Nadir	r	-0.39371	0.319284		-0.04265	-0.01264	-0.33434
	p	5.07E-05	0.001204		0.673547	0.900708	0.000675
Spas	r	-0.12169	0.046249	-0.04265		0.33467	0.115879
	p	0.227785	0.647731	0.673547		0.000666	0.250931
Mas	r	0.090093	-0.10673	-0.01264	0.33467		0.268981
	p	0.372707	0.290546	0.900707	0.000666		0.006809
IAS	r	0.304711	-0.4089	-0.33433	0.115879	0.268981	
	p	0.002053	p<0.001	0.000674	0.250931	0.006809	

Table 4: Spearman correlation for polysomnography and upper air way.

**Maxillo-mandibular-hyoid position and OSA severity (Table 5)**

No statistical relation with OSA severity was shown.

Parameter s		AHI	SO2	Nadir	H-ML	ANB	SNML
AHI	r		-0.34822	-0.39371	0.191222	0.033843	0.106655
	p		0.000385	0.00005	0.056676	0.738176	0.290899

SO2	r	-0.34822		0.319284	-0.06726	0.015669	0.107876
	p	0.000385		0.001204	0.506087	0.877033	0.285376
Nadir	r	-0.39371	0.319284		-0.04197	0.020116	0.016355
	p	5.07E-05	0.001204		0.678426	0.842535	0.871695
H-ML	r	0.191222	-0.06726	-0.04197		0.403115	0.277317

	p	0.056676	0.506087	0.678425		p<0.001	0.005217
ANB	r	0.033843	0.015669	0.020116	0.403115		0.267579
	p	0.738176	0.877033	0.842534	p<0.001		0.007115
SNML	r	0.106655	0.107876	0.016355	0.277317	0.267579	
	p	0.290899	0.285376	0.871694	0.005217	0.007115	

**Table 5:** Spearman correlation for polysomnography and mandibular hyoid.

**Palatal structure and OSA severity (Table 6)**

PH had no statistical relation with AHI and SO2 (p=ns), but had and inverse correlation with Nadir (r: -0.21698; p<0.05). PA presented an inverse relation with Nadir (r: -0.169, p<0.05) and a relation with MAS (r: 0.2375, p<0.05). An inverse relation between the PL and SO2 (r:-0.2324, p<0.05) and direct relation with IAS (r: 0.2765, p<0.05) was shown.

**UAS and maxillo-mandibular hyoid position**

SNML had an inverse relation with IAS (r: -0.32, p<0.05). ANB had an inverse relation to IAS (r: -0.24, p<0.05); No correlation between the hyoid position and the upper airway space was found (Table 7).

Parameter s	AHI	SO2	Nadir	PA	PL	PT	
AHI	r	-0.34822	-0.39371	0.051144	0.075106	0.192013	
	p		0.000385	0.00005	0.613318	0.457685	0.055641
SO2	r	-0.34822	0.319284	-0.0206	-0.23898	-0.1146	
	p	0.000385		0.001204	0.838788	0.016641	0.256218
Nadir	r	-0.39371	0.319284	-0.21698	0.08192	-0.25171	
	p	5.07E-05	0.001204		0.030125	0.41779	0.011528
PA	r	0.051144	-0.0206	-0.21698		0.015318	-0.11603
	p	0.613318	0.838788	P<0.05		0.879764	0.250304
PL	r	0.075106	-0.23898	0.08191	0.015318	0.394957	
	p	0.457685	0.016641	0.41779	0.879764		p<0.001
PT	r	0.192013	-0.1146	-0.25171	-0.11603	0.394957	

	p	0.055641	0.256218	0.011528	0.250304	p<0.001
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**Table 6:** Spearman correlation for polysomnography and palatal structure.

Parameter s	Spas	Mas	IAS	H-ML	ANB	SNML	
Spas	r		0.33467	0.115879	0.061274	0.116885	-0.05162
	p		0.000666	0.250931	0.544777	0.246811	0.610018
Mas	r	0.33467		0.268981	-0.13797	0.08665	-0.14479
	p	0.000666		0.006809	0.17104	0.391321	0.150628
IAS	r	0.115879	0.268981		-0.05806	-0.24281	-0.32366
	p	0.250931	0.006809		0.566127	0.014927	0.00102
H-ML	r	0.061274	-0.13797	-0.05806		0.403115	0.277317
	p	0.544777	0.17104	0.566127		p<0.001	0.005217
ANB	r	0.116885	0.08665	-0.24281	0.403115		0.267579
	p	0.246811	0.391321	0.014927	p<0.001		0.007115
SNML	r	-0.05162	-0.14479	-0.32366	0.277317	0.267579	
	p	0.610018	0.150628	0.00102	0.005217	0.007115	

**Table 7:** Spearman correlation for upper air way and mandibular hyoid.

**UAS and palatal structures**

PA had non-relation with UAS; PL presented a correlation with Spas (r:0.20; P<0.05), Mas (r:0.31; P<0.05) and (r:0.40; P<0.001); PT presented a correlation with IAS (r:0.33; P<0.001) (Table 8).

Parameter s	Spas	Mas	IAS	PA	PL	PT	
Spas	r		0.33467	0.115879	0.007443	0.206392	0.073192
	p		0.000666	0.250931	0.941409	0.039379	0.469258
Mas	r	0.33467		0.268981	0.171897	0.31771	-0.19122
	p	0.000666		0.006809	0.087245	0.001277	0.056677
IAS	r	0.115879	0.268981		0.016232	0.408471	0.33864

	p	0.25093 1	0.00680 9		0.87265 5	p<0.001	0.00056 8
PA	r	0.00744 3	0.17189 7	0.01623 2		0.01531 8	-0.11603
	p	0.94140 9	0.08724 5	0.87265 5		0.87976 4	0.25030 4
PL	r	0.20639 2	0.31771	0.40847 1	0.01531 8		0.39495 7
	p	0.03937 9	0.00127 7	p<0.001	0.87976 4		p<0.001
PT	r	0.07319 2	-0.19122	0.33864	-0.11603	0.39495 7	
	p	0.46925 8	0.05667 7	0.00056 8	0.25030 4	p<0.001	

**Table 8:** Spearman correlation for upper air way and palatal structures.

## Discussion

OSAs is a common condition that affect child and adults. Clinically two forms of OSA are decrypted: the primary and the secondary form. An alteration of the central nervous system is present in the primary form (central form) in which alteration of ventilation is related to an incoming of the nervous stimulus at the respiratory system. This type of OSAs has a more complex diagnosis and is more difficult to treat [22]. Reduction of upper airways width, obesity, obstructive factors such as adenoide-tonsillae hypertrophy, PAS reduction, redundant soft palate, craniofacial structures and prominent base of tongue were included in the secondary form classification [18].

Both the forms include a reduction of respiratory flow with an increase of bloody pressure and a reduction of oxygen saturation.

The secondary form is related to an obstruction of upper airway. These structures may be influenced by the maxillo-mandibular-hyoid position [23].

In the last years a great correlation of mandibular and hyoid position was shown. Many authors suggest that patients with a backward mandibular position and an increase of distance of hyoid to mandibular pane presented an increase of secondary OSAs risk [24].

The evaluation of cranio-facial structures included the palatal lenght and thickness too. An increase of palatal length and thickness were included as risk factors for secondary OSA pathogenesis [24,25].

In the present paper authors evaluated one-hundred patients affected by a mild to severe OSAs. A supine head-films was done end evaluated by a cephalometric analysis. Authors paired the cephalometric data to PSG data to evaluate the possible correlation between the craniofacial structures and secondary OSA.

The evaluation of cephalometric analysis showed a prevalence of backward and post routed mandible (ANB mean 3.832; SN-ML mean 33.15°), and an increase of ML-H (mean 23.21 mm). The upper airway space was reduced (SPAs 11.82 mm; Mas 5.92 mm; IAS 8.909 mm) and the palatal structure was increased (Length 43.27 mm; height 9.78 mm and angle 121.1°). The present data was similar to other researches [24-28].

In the present study a possible correlation between the cranio-facial structures and UAS was evaluated. The UAS influenced the severity of

OSA in the inferior part (i.e., IAS). IAS had a relation with AHI and inverse relation with SO2 and Nadir. Spas and Mas were not statistically related to OSA severity.

The correlation test (i.e., Spearman test) showed how the SPas and Mas had no correlation with the severity of OSA but a linear relation of IAS to AHI was evaluated. An increase of IAS was correlated to an increase of AHI, a reduction of SO2 and Nadir. Authors showed how IAS had correlation with AHI, SO2 and Nadir. No other structures presented a strict relation with PSG data. The maxillo-mandibular structures had no statistically relation with OSA severity; the palatal structure influenced the Nadir (PA p<0.05; PT p<0.05) and SO2 (PL p<0.05).

In the correlation test is showed how IAS was influenced by the mandibular position (i.e., a backward and post inclined position of the jaw increase the IAS). UA was not influenced by the Hyoid distance from the mandibular plane. A great correlation of PL (p<0.001) and PT (p<0.001) with IAS was evaluated.

## Conclusion

In the present paper authors evaluated one -hundred patients affected by secondary OSA. The study was done with a supine latero-lateral headfilms. The cephalometric evaluation showed how patients presented:

- a) Reduction of UAS;
- b) Post-inclination of the mandible;
- c) Increase of the ANB Angle
- d) Increase of palatal length, palatal height and palatal angle.

Authors correlated the craniofacial structures (maxillo-mandibular-hyoid position, palatal length, thickness and angle) and the upper airway space (IAS, MAS, sPAS) to the PSG data (AHI, SO2 and Nadir).

The papers showed:

- A great correlation between IAS and OSA data;
- A direct correlation between the palatal length and thickness with IAS;
- An inverse correlation between the mandibular post-inclination and backward position and IAS.

The paper presented three main limitations: 1) low numbers of patients evaluated; 2) BMI and 3) craniofacial structures evaluation on a bidimensional headfilms (i.e., latero-lateral headfilms). The strength of the paper was due to the fact that patients were evaluated in the supine position and the exclusion of excessive smoker patients.

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